Finally, another bundle was built up, consisting of a much larger number of fine annealed iron wires. With this the creeping was almost insensible.

It may be that the comparative absence of magnetic creeping, or "nachwirkung," in these last experiments is to be ascribed to the quickness with which the process of creeping completes itself in a finely divided mass of iron: in other words, that the process is practically complete in a time much shorter than the period of the magnetometer needle. The marked difference in effect between a solid core (a single thick wire) of soft iron and a laminated core (a bundle of fine wires) of the same material, suggests that in the former much more than in the latter the process of creeping is retarded by the eddy currents which are set up by those molecular movements in which the process itself consists.

[July 11th.—In seeking an explanation of the difference in behaviour it may be worth while to bear in mind that there is probably a considerable difference in molecular structure between a solid core and a laminated core of iron. If we accept the view that the magnetically neutral state is due to the molecular magnets forming closed rings, these rings will for the most part be closed within the limits of the separate constituent pieces of the laminated core, whereas in the solid core they may be much larger, their dimensions being limited only by those of the core itself.]

I have received very valuable help in these experiments from two students, Mr. David Low and Mr. William Frew, who have prosecuted a troublesome research with much patience and zeal.

III. "Note on the Thermo-electric Position of Platinoid." By J. T. Bottomley, M.A., F.R.S., and A. Tanakadate, *Rigakusi*. Received June 13, 1889.

In carrying out a series of experiments on radiation of heat by solid bodies, an investigation to which one of the present writers has for some time past devoted considerable attention, it became necessary, for a purpose which need not here be detailed, to select a thermo-electric pair of metals, of which one metal is essentially platinum, as it passes through glass. Various pairs were considered, and some trials were made; and it was finally determined to make use of platinum and platinoid. The latter metal is an alloy whose electrical and mechanical properties were investigated some years ago by one of the present writers;* and since that time it has

* J. T. Bottomley, 'Roy. Soc. Proc.,' 1885.

assumed considerable importance in the construction of electrical instruments and resistance coils. Partly on this account, and partly from present requirements, it became both interesting and necessary to determine the thermo-electric constants for a specimen of this alloy.

Platinoid is in composition very similar to German silver. In the manufacture of the alloy, however, phosphide of tungsten is employed; and although an exceedingly minute quantity of metallic tungsten remains in the alloy, yet the properties of the substance are in many respects remarkable. The metal is capable of being polished so as to be almost as beautiful as silver in appearance, having only a slightly darker and more steel-like colour; and when it has been polished it remains absolutely untarnished, even in the atmosphere of a large town, for years at any rate. It has very remarkable properties as to electric resistance. It possesses a very high resistance, while at the same time it has a much lower temperature variation of electric resistance than any other known metal or alloy. It has also, as Sir William Thomson has found, very excellent elastic qualities.

Although it is not proposed to use the platinoid with any metal other than platinum in the investigation on thermal radiation above referred to, it nevertheless seemed advisable, when these experiments were being undertaken, to determine its position with respect to some other metals. It was accordingly tried as a pair with platinum, iron, aluminium, and with two specimens of copper.

A low-resistance Thomson's reflecting galvanometer was specially prepared for the purpose of these experiments. The mirror was a plane parallel mirror of very excellent quality by Steinheil of Munich. Its deflections were observed by means of a telescope with cross-wires and scale, instead of by a lamp and scale. To avoid any influence of the suspending fibre (which even though of single cocoon silk fibre does with short fibres give an appreciable torsional resistance) the mirror was suspended by spider line. The suspending of a mirror, weighing with its magnet 0·2 gram, by a single spider line is a matter of some nicety and difficulty; but when it has been accomplished the result is so thoroughly satisfactory that it is easily admitted to be well worth a morning's labour.

To make the suspension two small pieces of very thin bristle or of hard-spun silk fibre or split horsehair are attached to the ends of a suitable length of spider line recently spun by a good large* spider. By means of these attachments, which are easily seen, the spider line can be handled. It is then brought over the galvanometer mirror; and great assistance is experienced in these operations, and in operations with single silk fibres, by performing them on the top of a piece of looking-glass laid on the table. The illumination from beneath of

* The body about as large as a pea.

the fibres makes it easy to do with these fine filaments that which is otherwise scarcely possible. The fibre is attached to the galvanometer mirror with the smallest possible speck of shellac varnish, the greatest care being taken not to varnish any part of the spider line. When the varnish has dried, the mirror can be lifted up by the spider line; caution being used at the moment of raising the one mirror off the surface of the other on account of the vacuum which is liable to be formed at the moment of separation. The mirror should be allowed to hang on the fibre inside a glass beaker for twenty-four hours at least, as the spider line stretches considerably for some time after the weight comes on it. A spider line which will carry a galvanometer mirror and magnet weighing 0·2 gram may have, according to an estimate made by one of the present writers, about $\frac{1}{700}$ of the torsional rigidity of a single cocoon silk fibre.

For the heating of the junctions, a number of glass vessels were blown, resembling the flasks, with neck and condensing tube, used for fractional distillation, but with the condensing tube projecting upwards into the air, so that the steam of a liquid boiling in the flask runs back into the flask on being condensed. Into the shorter neck of the flask was introduced a cork, which carried the thermo-junction and a mercurial thermometer; the thermo-junction being loosely bound to the bulb of the thermometer, or, at any rate, kept in close contact with the middle part of the thermometer-bulb. The cool junction was bound to the bulb of a second thermometer, which dipped into a vessel containing water at the temperature of the laboratory. The water was kept thoroughly stirred from top to bottom by a properly arranged stirrer.

In the heating flasks the vapours of the following liquids were used: alcohol, water, chlorobenzol, aniline, methyl salicylate, and bromobenzol.* The liquids were boiled vigorously, and the temperatures of the vapours were determined by means of the mercurial thermometer. Both the mercurial thermometers were compared directly with the air thermometer.† The obtaining of a set of points of temperature by this means was very satisfactory in every case except that of the liquid of highest boiling point, bromobenzol. In this case a curious phenomenon was observed.‡ In spite of the fact that the vapour of the substance was rushing strongly into the condensing tube and, indeed, out into the open air, at an elevation of 2 feet above the surface of the liquid it was found exceedingly difficult to keep the temperature of the various parts of the boiling flask anything like uniform. The vapour formed itself into layers of different temperatures, the parts of the flask nearest the surface of the liquid being the hottest. At

* Ramsay and Young, 'Chem. Soc. Journ. (Trans.),' 1885.

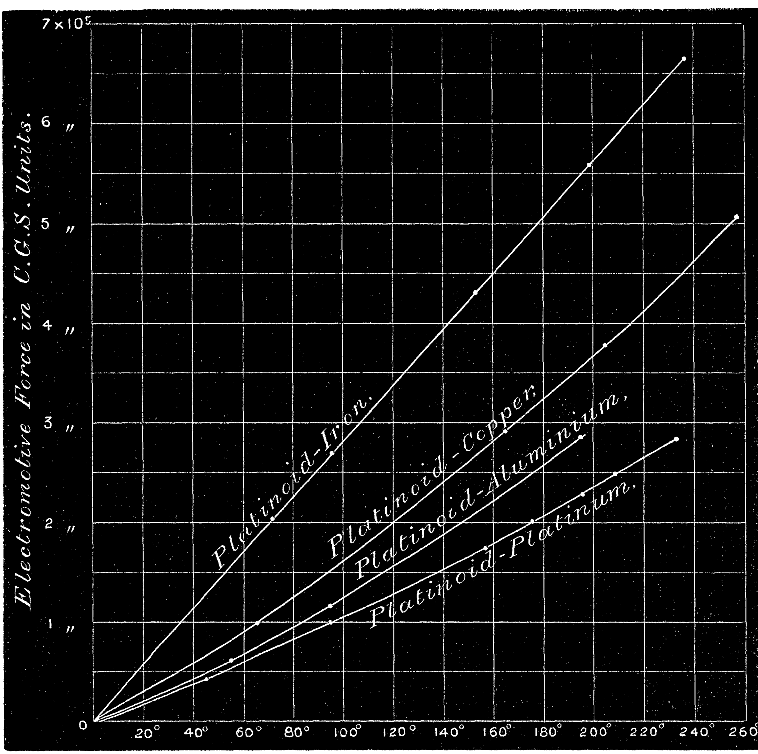
† J. T. Bottomley, 'Phil. Mag.,' August, 1888.

‡ Perhaps due to want of purity of the substance.

a height of $2\frac{1}{2}$ inches above the surface of the liquid the temperature was often found to be as much as 8° or 10° C. cooler than it was just above the surface. The difficulty could, to a certain extent, be overcome by putting a cloak of fine flexible wire gauze all round the upper part of the flask; but the greatest watchfulness was needed to avoid mistakes.

In order to reduce the results obtained from the readings of the galvanometer to absolute electromagnetic measure, a carefully prepared standard Daniell's cell was kept with its current always flowing through a known high resistance; and from time to time the galvanometer which was being used was thrown into the circuit, and the value of the galvanometer deflection determined. The electromotive force of the Daniell's cell was valued at 1·072 volts.

The results obtained are shown in the accompanying curves and tables.



In the curves the electromotive forces are shown as ordinates, the differences of temperature between the hot and cold junctions being indicated on the axis of abscissas. The electromotive forces are given

in C.G.S. units, and must be divided by 10^8 if it be desired to reduce them to volts. The differences of temperatures are given in centigrade degrees. The direction of the current in each of the cases represented, is from platinoid to the second metal of the pair through the hot junction.

Table I shows, in the way now well known,* the multiplier, at any temperature centigrade, which must be used, as factor with the difference of temperatures between the hot and cold junctions, in order to calculate the electromotive force in C.G.S. units. The algebraic sign corresponds with that used by Tait, and now adopted by Everett ('Units and Constants,' 2nd Edition, 1886).

Table I.

Platinoid-platinum...............	$-925-1{\cdot}16\times t$.
Platinoid-aluminium	$-985-4{\cdot}31\times t$.
Platinoid-iron	$-2916+0{\cdot}86\times t$.
Platinoid-copper (A)	$-1246-5{\cdot}44\times t$.
Platinoid-copper (B)	$-1294-4{\cdot}88\times t$.

Combining the results of Table I with those of Tait, reduced by Everett, we obtain the thermo-electric distance of platinoid from lead, taken as zero, at various temperatures centigrade. If any one of the wires platinum, aluminium, iron, or copper used by us, were identical with the wire of the same name used by Professor Tait, we should be able to deduce with exactness the distance of our platinoid wire from his lead wire. That, however, was not the case; and each of the secondary wires used by us gives us, as it were, a different result. Thus we have :—

Table II.

			Platinoid to lead.
From experiment	with	platinum	$-986-2{\cdot}26\times t$
,,	,,	aluminium	$-1062-3{\cdot}92\times t$
,,	,,	iron	$-1182-4{\cdot}01\times t$
,,	,,	copper (A)	$-1110-4{\cdot}49\times t$
,,	,,	copper (B)	$-1158-3{\cdot}93\times t$

Taking the mean of all of these, with the exception of the result for platinum, which we omit because different specimens of platinum are well known to differ thermo-electrically enormously among themselves, we obtain for the thermo-electric distance of platinoid from Professor Tait's lead wire $-1128-4{\cdot}1\times t$.

This result enables us to place platinoid in Tait's thermo-electric diagram. Its line is nearly parallel to those of palladium and German

* Tait, 'Edinburgh Roy. Soc. Trans.,' vol. 27, 1873, and Everett's 'Units and Constants,' 2nd Edition, 1886,—"Thermoelectricity."

silver, and slightly above the latter. It is, however, to be remembered that, in all probability, different specimens of platinoid alloy would give results differing considerably from that quoted above.

Appendix. By A. Tanakadate.

The following experiment on the torsional rigidity of spider line was carried out in the Physical Laboratory of the Imperial University of Japan, in 1884, and a notice of it was published in vol. 2 of *Rigakukyokwai Tassi* ('Proceedings of the Science Society') of that year in Japanese. It has not hitherto been described in English; and the absolute determination as referred to below by Mr. T. Gray of the rigidity of silk fibre makes an estimate of the rigidity of spider line possible.

The determination of the torsional rigidity was a relative one, and the experiment essentially consisted in finding the deflection of a small magnet due to a given twist of the suspending fibre: the magnet being placed in the earth's magnetic field (0·3 C.G.S.). The deflection was observed by the usual method of the reflected image of a fine wire stretched before a lamp.

The mirror magnet was first hung by a silk fibre of 31 cm. length, and placed in the usual way. The distance of scale from the mirror was 95 cm. When the torsion head of the magnetometer was turned through one complete revolution (2π) in either direction from zero, the image of the reflected wire was displaced through 8 mm. either way, or $8/2 \times 95 = 0·0042$ radians, or $864''$.

The silk fibre was now detached from the magnet, and a spider's line (newly spun) was attached in its stead. The length was 28 cm., the magnetometer was put into its place, and the torsion head was turned as before, but no appreciable deflection could be observed, even when the torsion head was turned through ten complete turns (20π). It was suspected then that the mirror might have been caught against the sides of its case; a close inspection, however, showed that it was quite free. The fibre was then shortened to 2·3 cm. (about one-twelfth its previous length), and the experiment was repeated. Ten complete turns of the torsion head gave a deflection of 1·5 mm.; or $·15/2 \times 95 = 0·00079$ radians $= 16·3''$ per turn.

In order to compare these deflections with each other, each deflection was reduced to that which would be given by a fibre of 1 cm. in length, by multiplying the deflections by the length of the fibre used. Thus, corresponding to the twist of one turn of the torsion head in a fibre of 1 cm. long, we have:—

For silk fibre	$864·0'' \times 31 = 26800''$
For spider line	$16·3'' \times 2·3 = 37·5''$

From this we get the ratio of the torsional rigidity of the spider line to that of the silk fibre to be 1 : 710.

The diameters of the fibres were microscopically measured, and gave the following values:—

Silk fibre....................	0·00091 cm.
Spider line	0·00028 „

If the elastic qualities of these fibres were the same, the ratio of the torsional rigidity would have come out $(28)^4 : (91)^4$, or 1 : 112; and hence the torsional rigidity of spider line is less than one-sixth of that of silk fibre of the same thickness.

The above result gives us only a relative value of the rigidities between the two fibres. If we take the mean value of the torsional rigidity of silk fibre to be 0·0012 C.G.S. on a length of 1 centimetre (not per square centimetre), as found by Mr. T. Gray,* the torsional rigidity of the spider fibre of the above experiment will be $\frac{0{\cdot}0012}{710} = 0{\cdot}000002$ C.G.S., the mode of reckoning being the same.

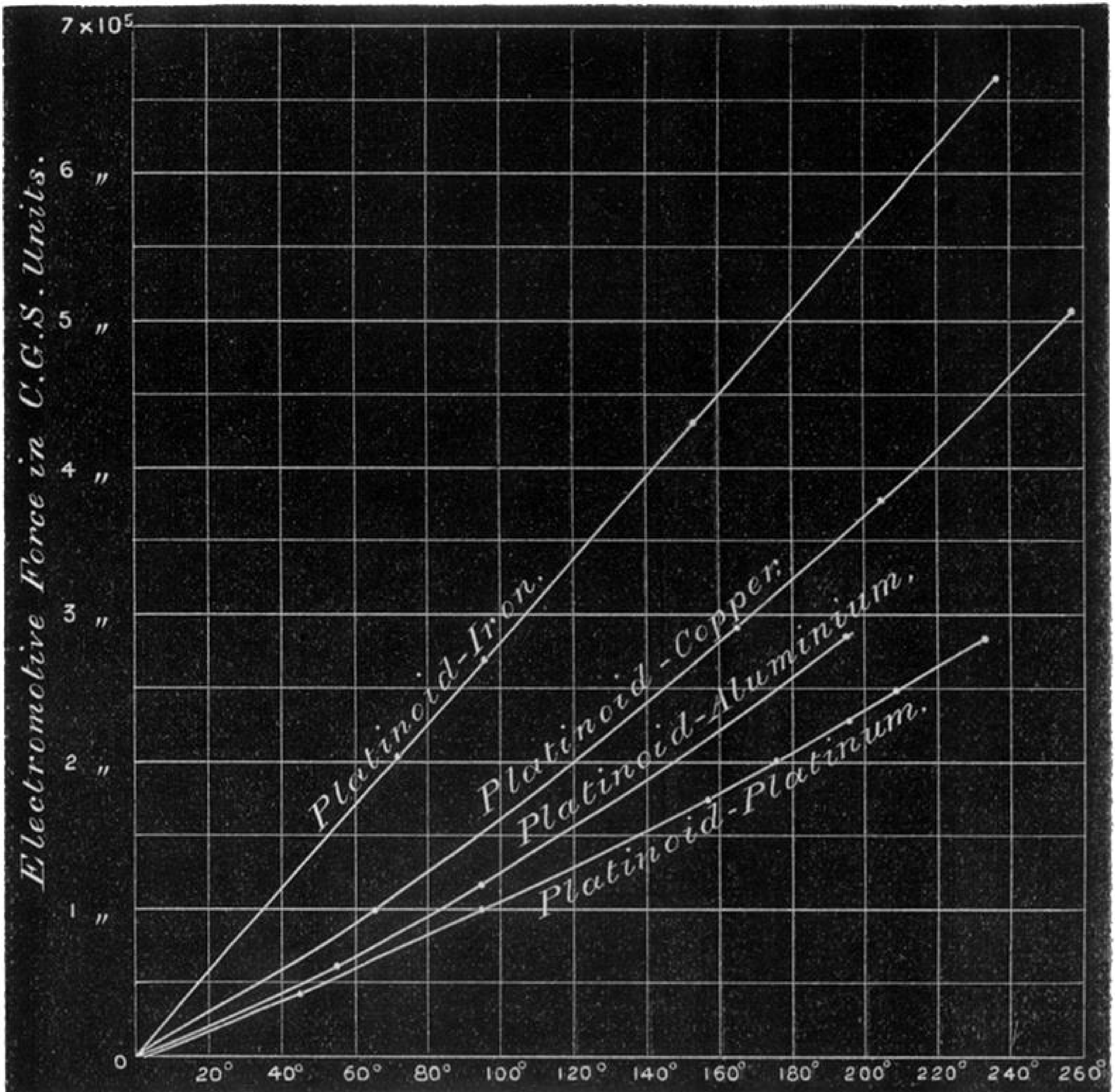
Mr. Gray's silk fibre may have had a slightly higher rigidity, as he states that it was boiled in water, while the fibre of the experiment just described was taken from those boiled in dilute potash water, as is the usual practice of preparing "mawata," which is a very soft kind of silk.

IV. "Specific Inductive Capacity of Dielectrics when acted on by very rapidly alternating Electric Forces." By J. J. Thomson, M.A., F.R.S., Cavendish Professor of Physics, Cambridge. Received June 17, 1889.

The researches of Dr. John Hopkinson have shown that in some dielectrics, of which the most conspicuous example is glass, the refractive index is not, as it ought to be on Maxwell's theory, equal to the square root of the specific inductive capacity, when the latter is measured for steady forces, or such as are reversed only a few thousand times a second. It is therefore desirable to measure the inductive capacity under circumstances which approach as nearly as possible to those which, according to Maxwell's theory, occur when light passes through a dielectric. This will be when the forces are reversed as rapidly as possible. In the following experiments the forces were reversed about 25,000,000 times per second.

The method consists in measuring the wave-length of the electrical vibrations given out by a condenser whose plates are in electrical connexion. If C is the capacity in electrostatic measure of the con-

* 'Phil. Mag.,' 1887.



Electromotive Force in C.G.S. Units.
7×10⁵
6 "
5 "
4 "
3 "
2 "
1 "
0
20° 40° 60° 80° 100° 120° 140° 160° 180° 200° 220° 240° 260°
Platinoid-Iron.
Platinoid-Copper.
Platinoid-Aluminium.
Platinoid-Platinum.